Using Surface-Based GPS Receivers to Validate AIRS Column-Integrated Water Vapor Retrievals

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Overview

- GPS-IPW measurement principles
  - GPS-IPW vs.other GPS meteorology
  - Hardware and data collection
  - Signal processing and IPW derivation
- GPS-IPW data products
  - Examples and statistics
- GPS-IPW for AIRS validation
  - Strengths and limitations
  - Schedule and collaboration
  - Special needs

GPS Meteorology

GPS Meteorology

Ground Based

Measures signal delay from fixed point on ground.

Integrated Precipitable Water Vapor

- Gives total precipitable water vapor directly above site
- Expanding operational network implemented

Slant-Path Signal Delay

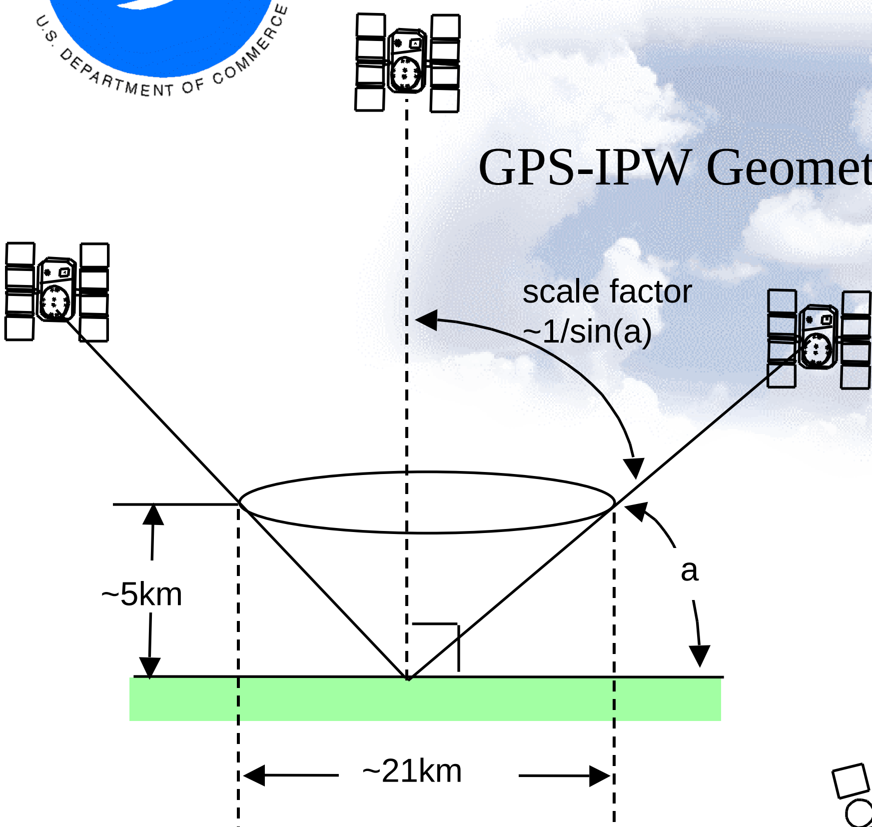
- Gives line-of-sight signal delay to each satellite in view
- Concept demonstrated. Techniques under investigation

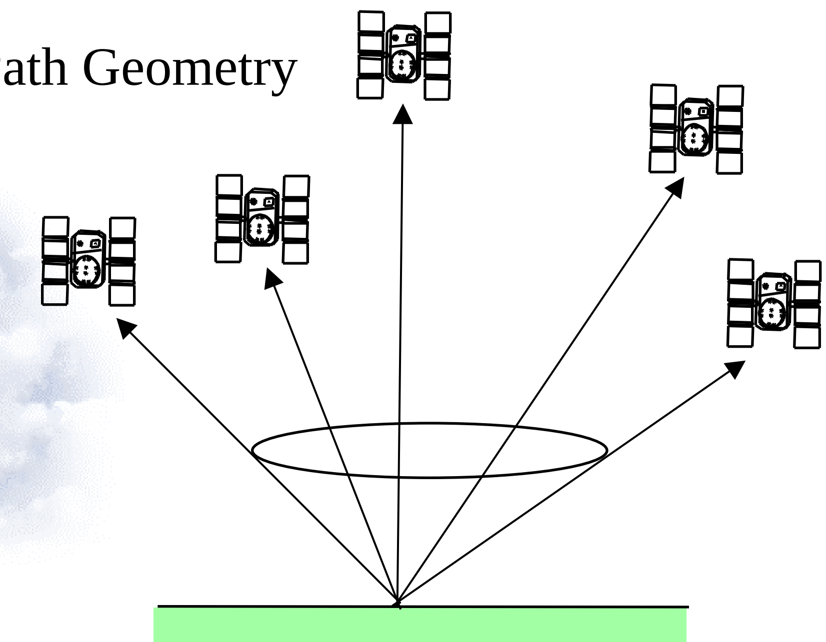
Space-Based Occultation

Measures signal delay from LEO satellites with near-global coverage

- Provides profiles of integrated refractive index (~ 1km x 300km)
- GPS/MET Demo 1995
  SAC-C 2001
  COSMIC 2005
  GRAS 2005
  GPSOS 2008

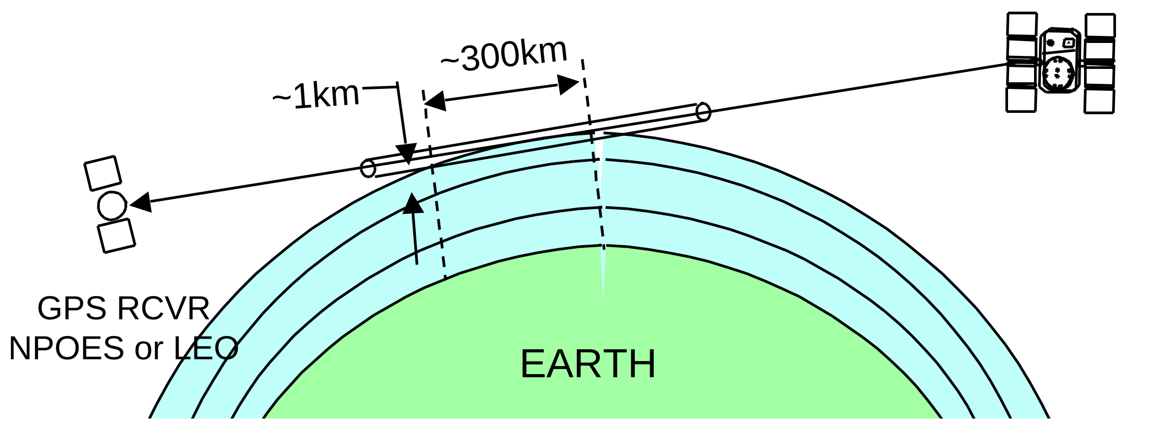
GPS Meteorology Overview





NOTES: Average elevation angle (a) at mid latitudes ~ 25^0

Mapping functions determine how the signal delay changes with elevation angle.



Space Based Geometry

Fundamental Measurement

$$L_s = \int n(s)ds$$

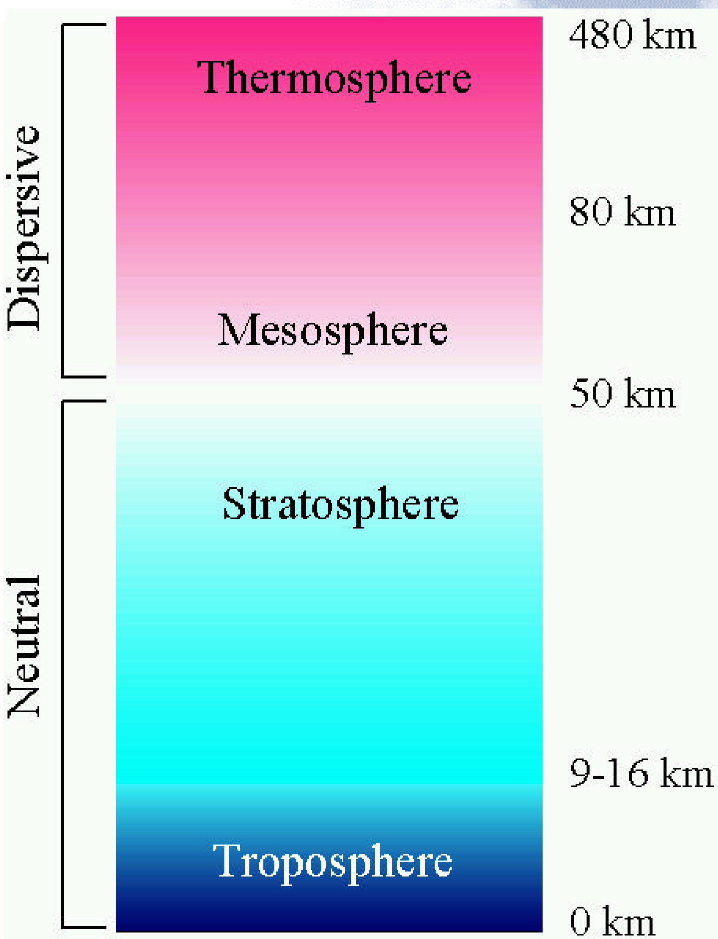
Typical GPS-IPW Demonstration Network Sites

NOAA Wind Profiler Sites
Platteville, CO (PLTC)

Other NOAA Sites
Blacksburg, VA WFO (BLKV)

USCG and USDOT DGPS Sites
Cape Canaveral, FL (CCV3)

GPS Signal Propagation Through The Atmosphere



- Propagation velocity of EMR in the ionosphere depends on frequency and the refractive index (n) associated with electron density.

- Ionospheric propagation effects can be eliminated using dual frequency receivers since:

$$M_{IF} \quad 2.546\, M_{L1} - 1.984\, M_{L2}$$

- Below 30 GHz, EMR propagation velocity in the neutral atmosphere depends on the refractive index associated with temperature, pressure and water vapor.

Tropospheric Signal Delay

- After position is estimated, there are always residual errors caused by slowing and bending of the GPS signal in the neutral atmosphere - the Tropospheric Signal Delay.

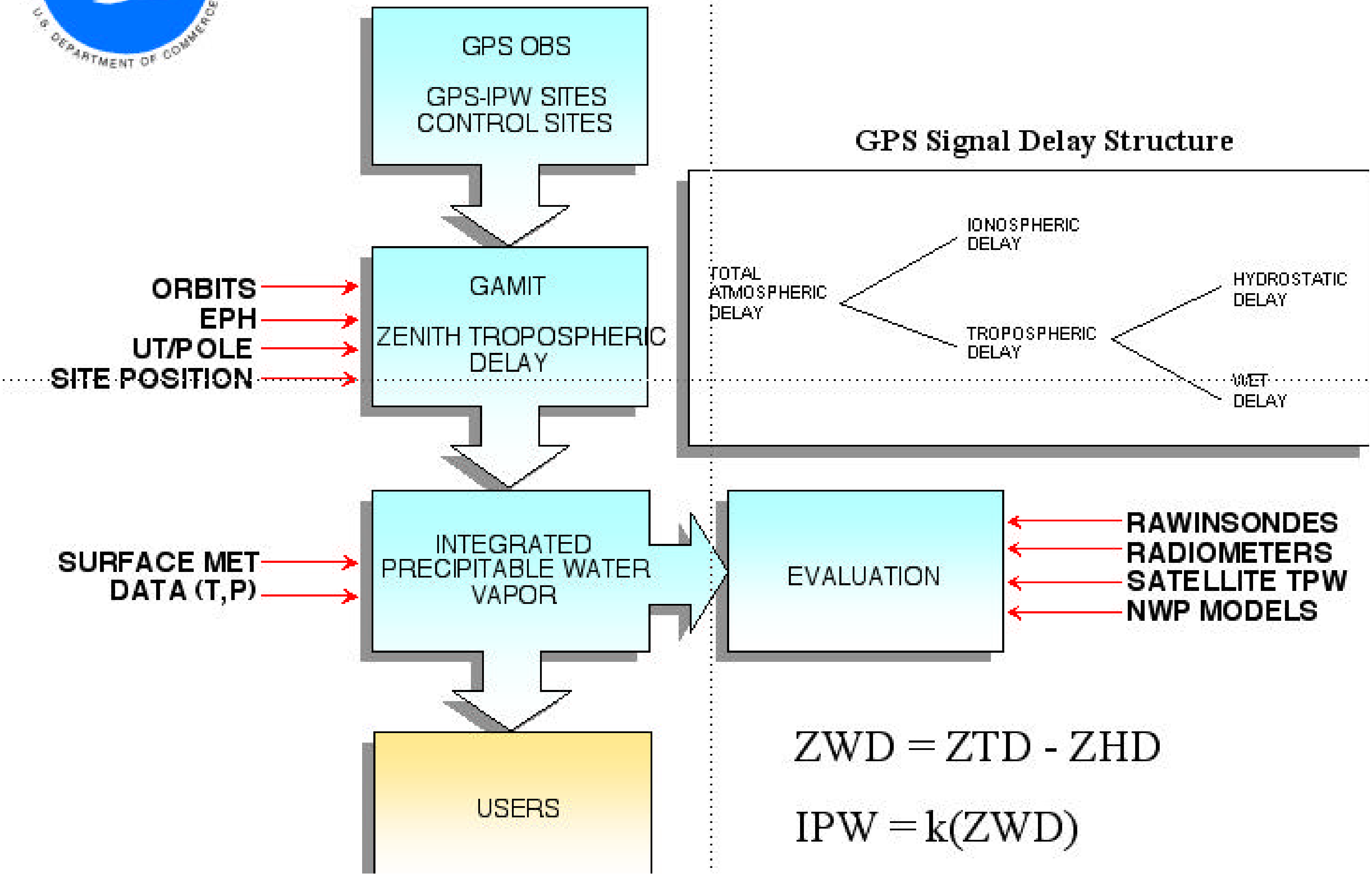
- In terms of the refractivity of the neutral atmosphere:

$$N = 10^6(n-1) = k_1 \frac{P_d}{T} + k_2 \frac{P_v}{T} + k_3 \frac{P_v}{T^2}$$

where P_d and P_v are the partial pressures of the dry and wet components of the atmosphere; k_1, k_2, and k_3 are the gas constants; and T is temperature.

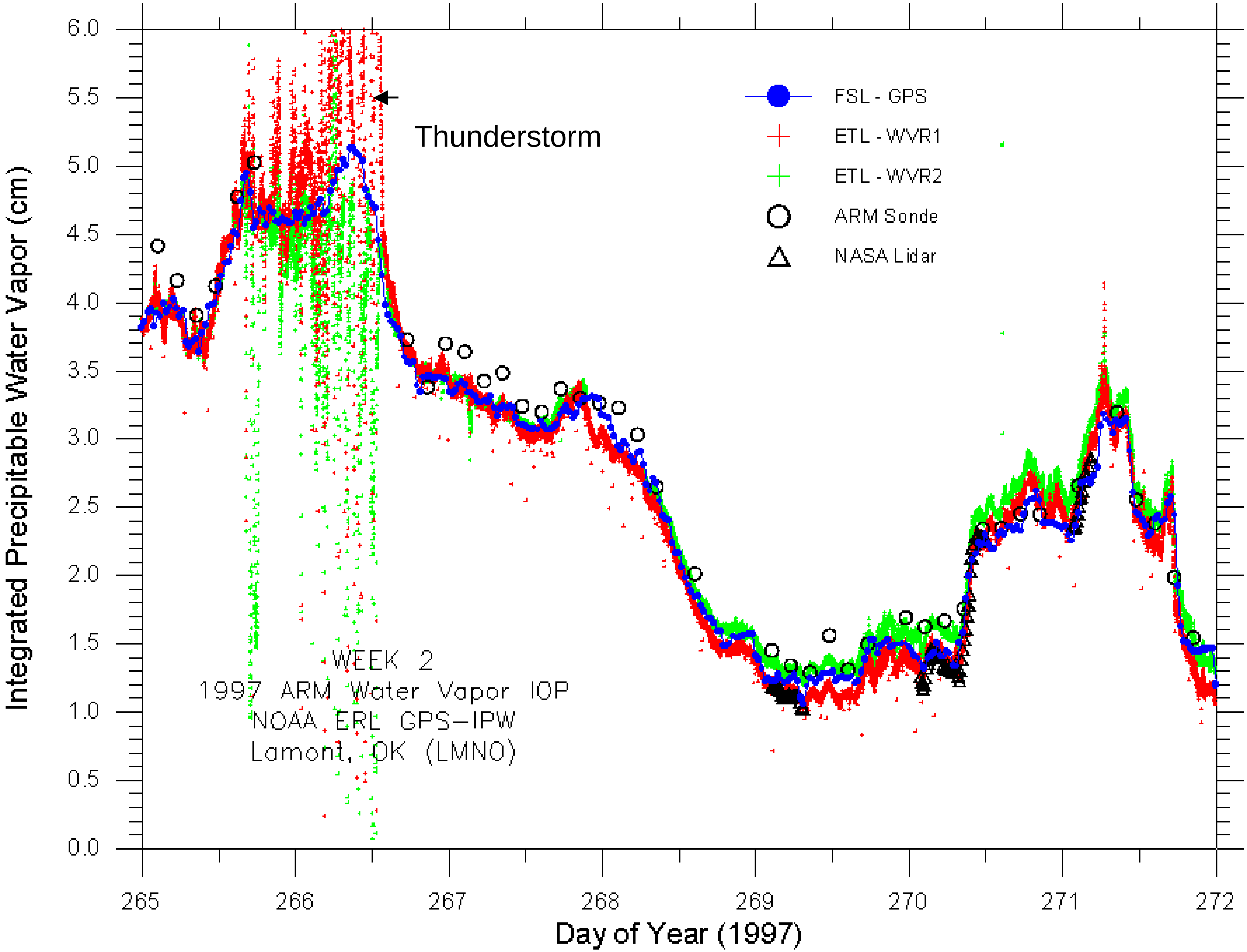
- We apply a mapping function to estimate the signal delay that would be observed if each satellite was directly overhead, and average the results to give ZTD.

Generalized GPS-IPW Data Processing Scheme

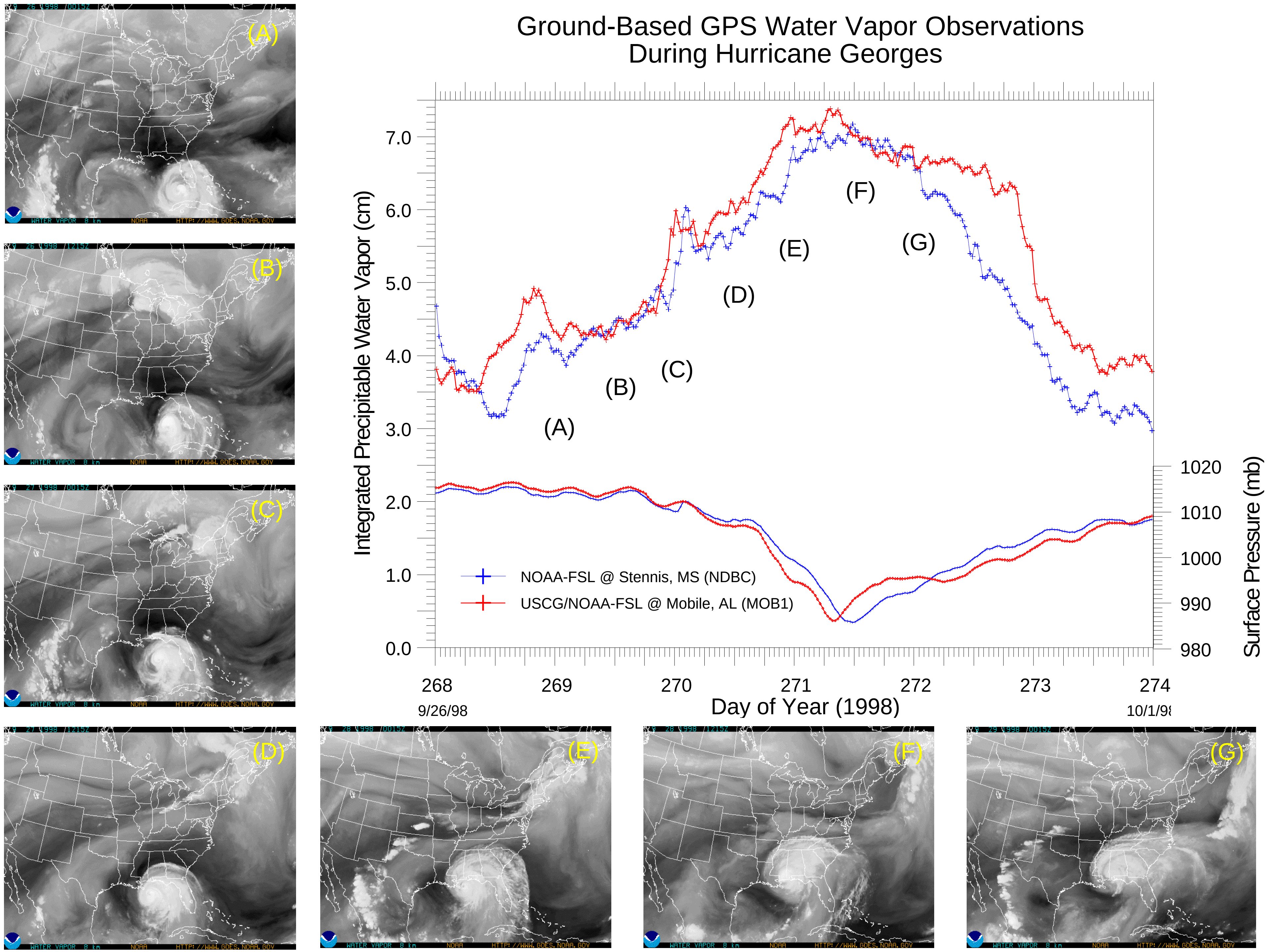


$$ZWD = ZTD - ZHD$$

$$IPW = k(ZWD)$$

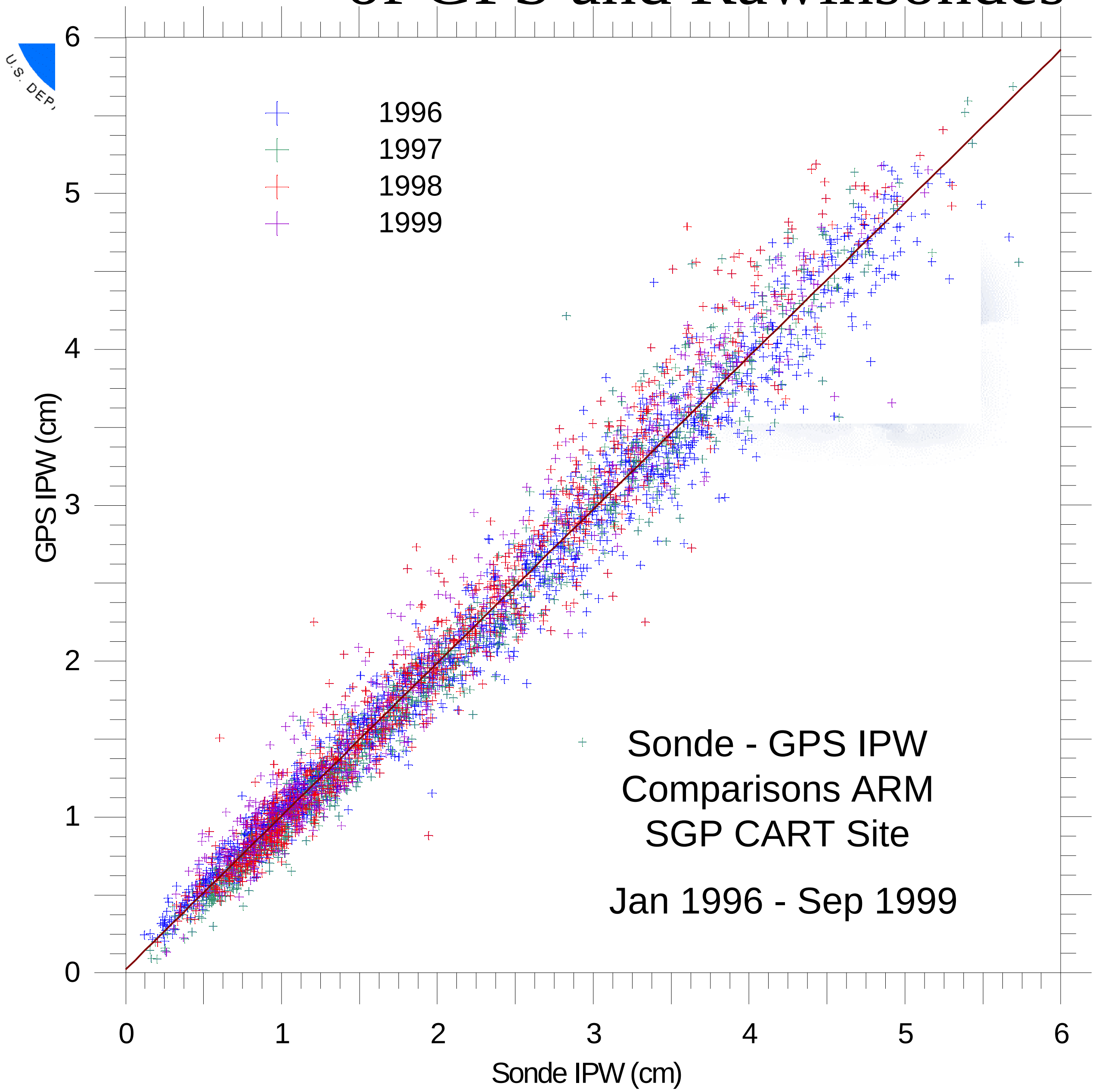


Integrated Precipitable Water Vapor (cm)
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
265
266
267
268
269
270
271
272
Day of Year (1997)
Thunderstorm
FSL - GPS
ETL - WVR1
ETL - WVR2
ARM Sonde
NASA Lidar
WEEK 2
1997 ARM Water Vapor IOP
NOAA ERL GPS-IPW
Lamont, OK (LMNO)


Ground-Based GPS Water Vapor Observations
During Hurricane Georges
Integrated Precipitable Water Vapor (cm)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Surface Pressure (mb)
1020
1010
1000
990
980
268
269
270
271
272
273
274
9/26/98
10/1/98
Day of Year (1998)
NOAA-FSL @ Stennis, MS (NDBC)
USCG/NOAA-FSL @ Mobile, AL (MOB1)
(A)
(B)
(C)
(D)
(E)
(F)
(G)


900 km
900 km
EXPLANATION
NOAA GPS-IPWV Sites
USCG/USACE DGPS Sites
DoT NDGPS Sites
Other Agencies or Institutions
Filled = Operational, Open = Planned
UPDATED: 10.30.01

Long-Term Comparison of GPS and Rawinsondes



1996
N = 1382
Mean Dif. = 0.0346 cm
Std. Dev. = 0.1977 cm
Corr. = 0.9886

1997
N = 813
Mean Dif. = 0.0501 cm
Std. Dev. = 0.1965 cm
Corr. = 0.9874

1998
N = 771
Mean Dif. = -0.0431 cm
Std. Dev. = 0.2308 cm
Corr. = 0.9817

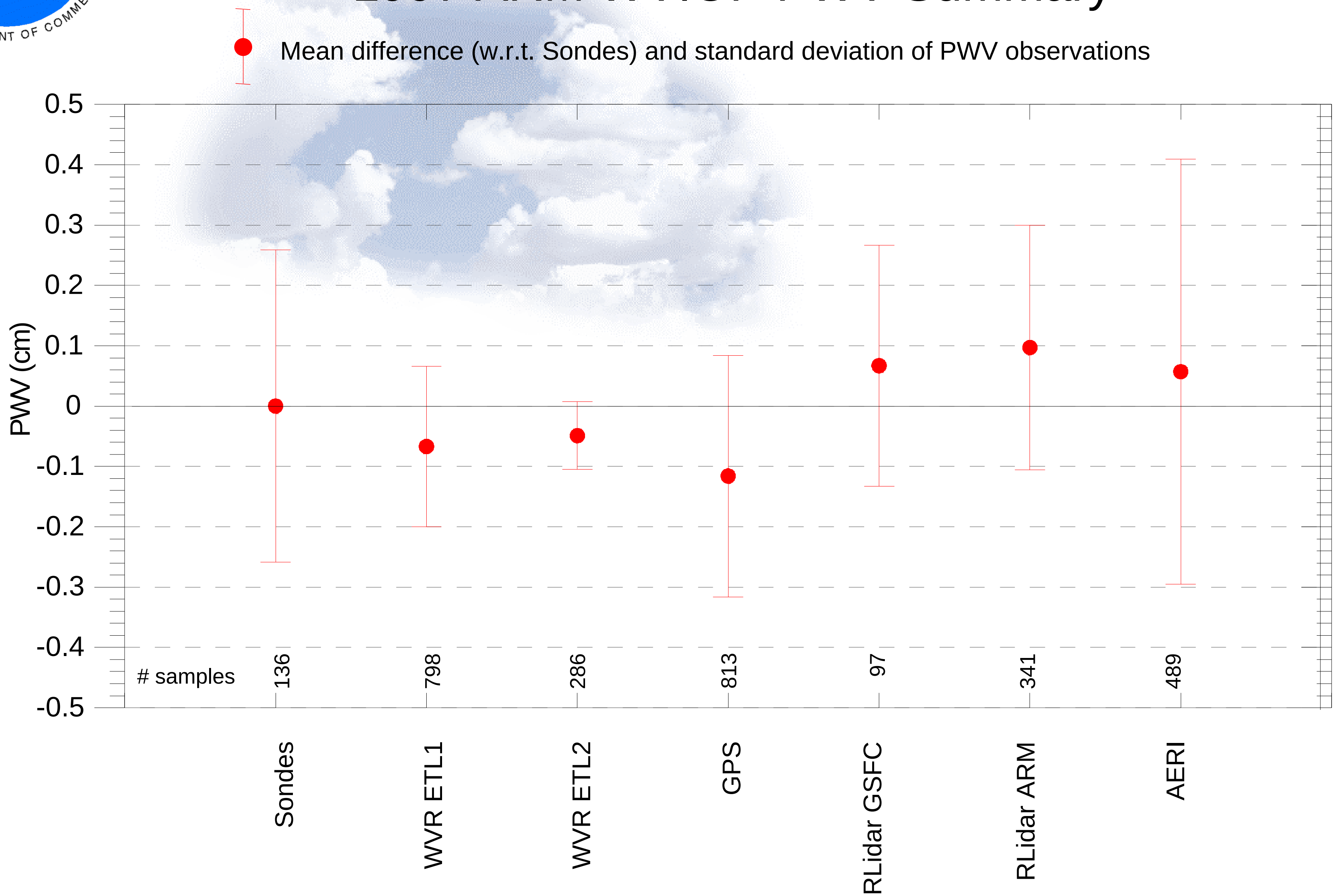
1999
N = 551
Mean Dif. = -0.0460 cm
Std. Dev. = 0.2070 cm
Corr. = 0.9851

1996 - 1999
N = 3600
Mean Dif. = 0.0080 cm
Std. Dev. = 0.2102 cm
Corr. = 0.9854

Equation of best fit line
Y = 0.9876125443 * X + 0.01837114798

PWV Observing System Accuracy

1997 ARM WVIOP PWV Summary



GPS-IPW for AIRS Validation

- Strengths
  - All weather, high accuracy, 30 minute resolution,
  - Operational
- Limitations
  - Currently restricted to CONUS
  - No vertical resolution; for profiles, serves as constraint
- Schedule
  - Ready immediately
  - Need to integrate w/ Wolf *et al* for "All-way" match-ups
- Special needs - None